

**EE234**

**Microprocessor Systems**

**Midterm Exam 2**

**Nov. 16, 2022. (2:10pm – 3pm)**

**Instructor: Dae Hyun Kim ([daehyun@eecs.wsu.edu](mailto:daehyun@eecs.wsu.edu))**

**Name:**

**WSU ID:**

Problem	Points	
1	10	
2	30	
3	40	
Total	80	

## Problem #1 (Stack, 10 points)

\* Notice that SP (R13) points to the bottommost element in the stack.

The following shows the register file (RF) and the main memory map.

R15 (PC)		0x0418	0x0410
R14 (LR)	0x0400	0x0414	0x0400
R13 (SP)	0x0408	0x0410	0x0404
	...	0x040C	0x0408
R2	0x0404	0x0408	0x040C
R1	0x041C	0x0404	0x0418
R0	0x0414	0x0400	0x0414

RF Main memory

Show the values of R0, R1, R2, SP, and the main memory map after the following instructions are executed.

POP {R0}  
POP {R2}  
PUSH {R1}  
PUSH {R0}  
POP {R1}  
PUSH {R2}

R15 (PC)		0x0418	
R14 (LR)	0x0400	0x0414	
R13 (SP)		0x0410	
	...	0x040C	
R2		0x0408	
R1		0x0404	
R0		0x0400	

RF Main memory

## Problem #2 (Subroutines and Stack, 30 points)

Answer the following questions for the assembly code shown below.

```
main:          find:          find_1:
MOV R0, #4     PUSH {LR}          ADD R0, R0, #4
MOV R1, #6     PUSH {R0}          PUSH {R2}
MOV R2, #0     PUSH {R1}          PUSH {R0}
PUSH {R2}     LDR R0, [SP, #16]  PUSH {R1}
PUSH {R0}     LDR R1, [SP, #12]  BL find
PUSH {R1}     CMP R0, R1        POP {R2}
BL find      BLT find_1        POP {R2}
POP {R1}     CMP R0, R1        POP {R2}
POP {R0}     BGT find_2        STR R2, [SP, #20]
POP {R2}     STR R0, [SP, #20]  B find_ret
B end        find_ret:
end:         POP {R1}          find_2:
// end of code POP {R0}          ADD R1, R1, #6
              POP {LR}        PUSH {R2}
              BX LR          PUSH {R0}
                             PUSH {R1}
                             BL find
                             POP {R2}
                             POP {R2}
                             POP {R2}
                             STR R2, [SP, #20]
                             B find_ret
```

- (1) (10 points) What is the value stored in R2 when the program ends?
- (2) (10 points) How many times is the "PUSH {LR}" statement (the first line of the "find" subroutine) executed?
- (3) (10 points) If we replace #4 by #7 (the first line after the "main:" label and the first line after the "find\_1" label) and #6 by #8 (the second line after the "main:" label and the first line after the "find\_2" label), what value will R2 have when the program ends?



### Problem #3 (Subroutines and Stack, 40 points)

The “com” function below computes  $f(n)$  recursively for the sequence  $f(n) = f(n-1) + f(n-2) + f(n-3)$  with the initial values  $f(1) = f(2) = f(3) = 1$ .

```
int main () {
    int n, s;
    ...
    s = com (n);
}

int com (int n) {
    if ( (n >= 1) && (n <= 3) )
        return 1;
    else
        return com(n-1) + com(n-2) + com(n-3);
}
```

Here is the main function:

```
main:
    // Addr(n) = SP+4
    // Addr(s) = SP
    LDR R0, [SP, #4]
    PUSH {R0} // placeholder for the return value
    PUSH {R0} // n
    BL com
    POP {R0}
    POP {R0} // s
    STR R0, [SP]
    // end of code
```

Write an assembly code for the “com” function.

